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FOREST RESEARCH NOTES

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION

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RATES OF INITIAL SPREAD OF FREE-BURNING FIRES ON THE NATIONAL FORESTS OF CALIFORNIA

By

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RATES OF INITIAL SPREAD OF FREE-BURNING FIRES

ON THE NATIONAL FORESTS OF CALIFORNIA

By C. A. Abell
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As early as 1914 Coert DuBois[2/] and his staff recognized that knowledge of the rates at which fires spread was essential to sound fire control planning, strategy, and tactics, and therefore designed the fire report form so that such data might be accumulated. Although the individual fire report form has changed appreciably since that time, the supply of data has grown continuously. The need for summarizing this practical fire experience is still present. While more accurate knowledge of the factors influencing fire behavior and their effects is also required, and is being obtained, the information on fire reports is too valuable to remain unused. The data presented here are the results of recorded observations made on more than 9500 fires by Forest Service officers and guards.

These data have already been used for evaluating existing and proposed suppression squad locations in the Fire Replanning Project[3/] which contributed in a material way to the work necessary for summarization. It is felt, however, that the possibilities of broader utilization of the results of this study warrant general distribution of the information among forest officers and to other agencies engaged in the protection of wild lands from fire.

The accompanying curves show graphically the rates of initial spread as calculated for each important inflammability zone on the different forests. Curves are also presented showing rates of spread by forests for all zones therein, and, in addition, average curves for each zone for all northern forests and for all southern forests. The use of curves for presenting the data may perhaps appear cumbersome, but is necessary to a complete picture because the rates are not strongly grouped around some central value. If they were, then any fire would have approximately a 50-50 chance of spreading either faster or slower than the

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1/ Maintained at Berkeley, California, in cooperation with the University of California.

2/ DuBois, Coert. Systematic fire protection in the California forests. U.S.D.A. unnumbered publication. 1914.

3/ A nation wide reanalysis of fire control requirements begun by the Forest Service in 1937. The work in the California Region was done under the supervision of P. D. Hanson in the Regional Forester's office.

average and the average would mean what one ordinarily assumes. It should be carefully noted, and the curves emphasize the fact, that usually but about 25 percent of the fires spread faster than the weighted averages shown in table 1. Use of the averages in calculating probabilities therefore automatically introduces a safety factor which is probably not undesirable.

Rate of initial spread was calculated from data contained in individual fire report Forms 929 for fires on the national forests during the years 1925-1937, inclusive. Perimeter on discovery was subtracted from perimeter when reached and the result divided by the elapsed time, discovery to arrival. Perimeters were used equivalent to 1.5 times the circumference of circles with areas equal to the "area on discovery" and "area when reached" as given in the report. Initial spread rate was not computed for all fires. Some reports had data missing or obviously erroneous -- spread was not computed for these. Another large group for which spread was not calculated contained fires originating in snags, single trees, buildings, machinery, or camp fires, where the actual time that the fire spread in natural litter before attack was unknown. Some of these fires for which spread was not computed became large fires. However, since the main purpose of the study was to measure the spread probabilities in the different zones, such cases were excluded because they were certain to distort the results.

After calculation of rates of spread a tabulation was made for each zone on each forest showing the number of fires in the zone that spread at different rates. The numbers of fires in each table were then cumulated from the fastest spreading to the slowest spreading and these cumulative numbers expressed as a percent of the total number of fires for which spread data were available in that zone on that forest. The cumulative percentages arrived at in this way were plotted to define the curves presented. Curves were not prepared for those zones in which data were apparently too scanty, but these data were all used in defining the curves which pertain to more than one forest. The reliability of the individual curves may be judged from the number of fires used, which is stated on each curve. The curves are read as follows -- taking Angeles Zone II (page 9, fig. 11) as an example. Approximately 19 percent of the fires in Zone II spread at a rate of 48 chains perimeter per hour or faster; 30 percent of the fires spread at the rate of 26 chains perimeter per hour or faster.

Average rates of spread shown in table 1 were calculated from the same data used for the curves. The average rate for any geographical unit (zone, forest, etc.) was derived by multiplying the number of fires in each rate of spread class in that unit by the rate of spread for the class midpoint, then dividing the sum of all these products by the number of fires in the unit. Discrepancies in average spread rate between the same zones on different forests may be ascribed to, among other things, the relative frequency of fires in different fuels. For example, the Sierra Zone I with relatively high proportion of grass and brush fires has a high average rate whereas the Eldorado Zone I with a lower proportion of fires in similar fuels has a low average rate.

The inflammability zones referred to are those used in the Transportation Planning Project completed in 1936. Wherever zone is mentioned on curves or in table 1 the corresponding prescribed travel time is also indicated. In order that the data may be more useful to all protection agencies a brief description of the inflammability zones follows:

Northern Forests

Inflammability Zone I (one-half hour travel).
Consists of ponderosa pine and mixed conifer stands containing over one-half ponderosa pine, brushfields, grassland, and woodland within or below the ponderosa pine type.

Inflammability Zone II (1 hour travel).
Mixed conifer type containing less than one-half ponderosa pine. Brush areas within the type.

Inflammability Zone III (2 hours or more travel).
Alpine; generally lands above Zones I and II.

In addition to these three standard zones there are two special cases. On the Mendocino National Forest Zone VI is a brush zone. The Trinity National Forest has a special brush and grass Zone IA.

Southern Forests

Inflammability Zone I (15 minutes travel).
Grass, buckwheat, sage, woodland.

Inflammability Zone II (15 minutes travel).
Chamise, mixed chaparral, bigcone spruce.

Inflammability Zone III (one-half hour travel).
Dense woodland.

Inflammability Zone IV (one half hour travel).
Pine, mixed conifer.

Inflammability Zone V (1 hour travel).
Pinon, juniper, desert shrubs.

Inflammability Zone VI (extended travel).
Barren, semi-barren, sub alpine.

Acknowledgment

Assistance in the preparation of these materials was furnished by the personnel of Works Progress Administration Official Project 765-08-3-16.

CALIFORNIA NATIONAL FORESTS

Table 1.- Number of fires and average rates of initial spread, in chains perimeter per hour, by forests, by inflammability zones. Data from fires occurring during the years 1925-1937, inclusive.

Forest	All Free-burning fires		Zone I One-half hour travel		Zone II One hour travel		Zone III Two hours travel	
	No.fires	Ave.R.I.S.	No.fires	Ave.R.I.S.	No.fires	Ave.R.I.S.	No.fires	Ave. R.I.S.
Northern forests								
Eldorado	346	9.1	146	10.1	98	9.9	39	1.9
Klamath	767	14.5	188	23.3	137	11.4	341	10.6
Lassen	794	10.7	211	20.8	434	5.7	86	4.3
Mendocino	339	22.6	198	25.1 1/	66	8.1	11	5.3
Modoc	504	13.6	26	19.0	356	9.8	59	6.2
Plumas	1223	15.1	698	16.9	366	10.1	65	6.5
Sequoia	364	17.7	108	27.5	86	5.9	86	8.4
Shasta	1592	17.5	1062	19.0	284	9.1	88	7.0
Sierra	434	26.4	205	34.7	110	12.0	63	2.3
Stanislaus	405	18.6	226	23.2	114	7.8	38	4.3
Tahoe	864	12.0	345	19.1	360	6.9	154	7.7
Trinity	605	18.5	152	26.5	230	13.3	165	10.0
All northern forests	8237	15.9	3565	20.1	2641	8.9	1195	7.9
Southern forests			15 minutes travel		15 minutes travel		One-half hour travel	
Angeles	238	25.5	29	24.7	116	29.7	27	38.0
Cleveland	282	39.9	72	52.3	140	31.7	46	50.0
Los Padres	255	35.5	88	42.9	107	33.5	13	46.0
San Bernardino	529	20.2	32	35.5	209	28.1	37	9.4
All southern forests	1304	28.4	221	42.5	572	30.3	123	34.8

1/ Entry under Mendocino, Zone I represents combined number of fires in Zones I and VI, both of which required one-half hour travel according to the transportation plan.

CALIFORNIA NATIONAL FORESTS

Table 1, Con'd.- Number of fires and average rates of initial spread, in chains perimeter per hour, by forests, by inflammability zones. Data from fires occurring during the years 1925-1937, inclusive.

Forest	Zone IV		Zone V		Zone VI	
	No.fires	Ave.R.I.S.	No.fires	Ave.R.I.S.	No.fires	Ave.R.I.S.
Northern forests						
Eldorado	–	–	39	2.2	–	–
Klamath	–	–	–	–	–	–
Lassen	–	–	–	–	–	–
Mendocino	–	–	–	–	106	30.2
Modoc	–	–	11	37.3	–	–
Plumas	56	27.2	–	–	–	–
Sequoia	–	–	–	–	–	–
Shasta	–	–	–	–	–	–
Sierra	–	–	–	–	–	–
Stanislaus	–	–	15	40.0	–	–
Tahoe	–	–	–	–	–	–
Trinity 2/	–	–	–	–	–	–
All northern forests	56	27.2	65	16.9	106	30.2
Southern forests	One-half hour travel		One hour travel		Extended travel	
Angeles	22	7.2	6	21.5	16	3.0
Cleveland	16	9.0	–	–	–	–
Los Padres	16	9.2	14	12.9	3	48.7
San Bernardino	204	10.8	19	5.9	18	28.6
All southern forests	258	10.3	39	10.8	37	19.1

2/ The Trinity National Forest has in addition a zone "IA" with 41 fires and average R.I.S. of 40.9 chains. All Trinity fires rezoned by W. L. Travis in 1940. Above Trinity data represent the results after rezoning and do, therefore, not agree with previous data sent out for replanning use in 1939.

Figure 1

ALL NORTHERN FORESTS (12)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
½ HOUR TRAVEL

BASIS: 3565 FIRES
1925-1937 FIRE REPORTS

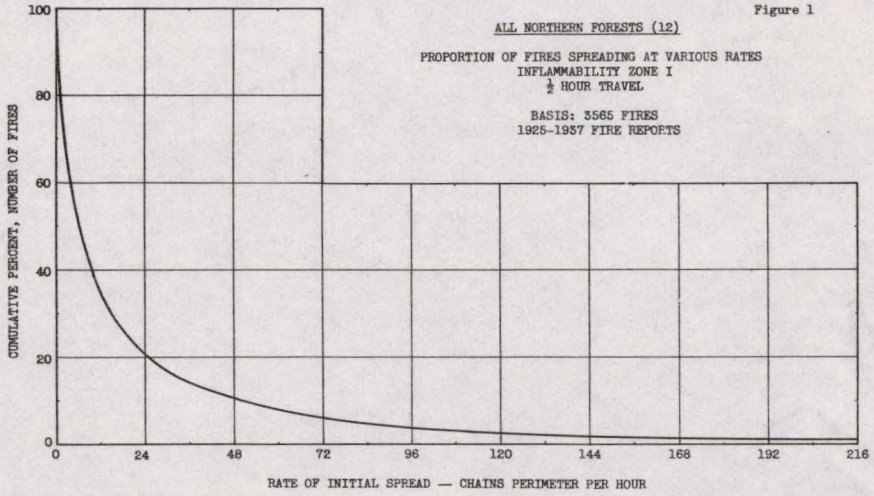


Figure 2

ALL NORTHERN FORESTS (12)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 2641 FIRES
1925-1937 FIRE REPORTS

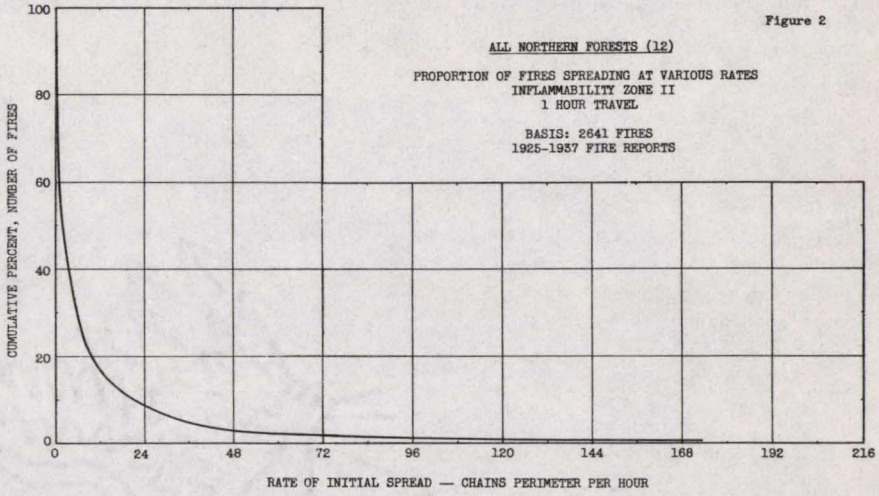


Figure 3

ALL NORTHERN FORESTS (12)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 1195 FIRES
1925-1937 FIRE REPORTS

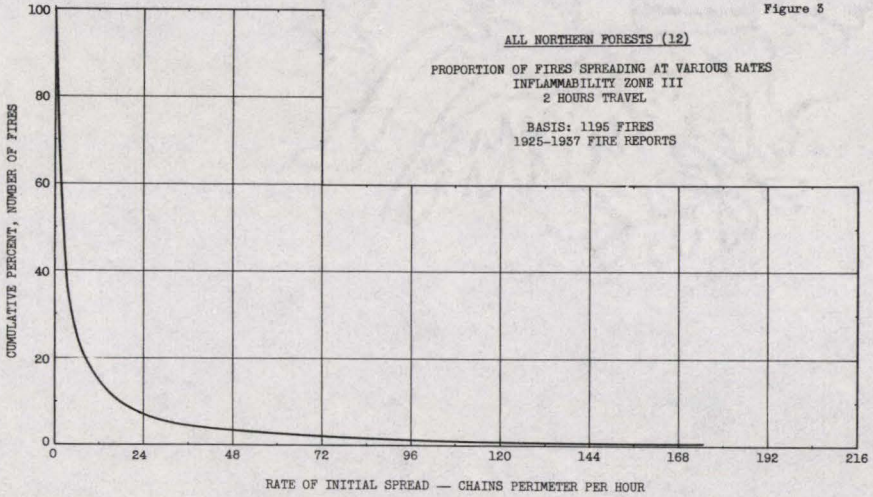


Figure 4

ALL SOUTHERN FORESTS (4)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
15 MINUTES TRAVEL

BASIS: 221 FIRES
1925-1937 FIRE REPORTS

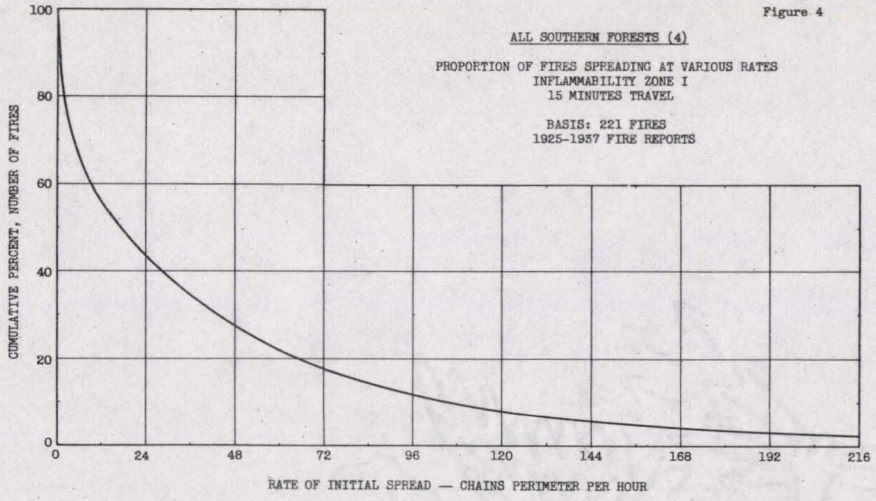


Figure 5

ALL SOUTHERN FORESTS (5)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
15 MINUTES TRAVEL

BASIS: 572 FIRES
1925-1937 FIRE REPORTS

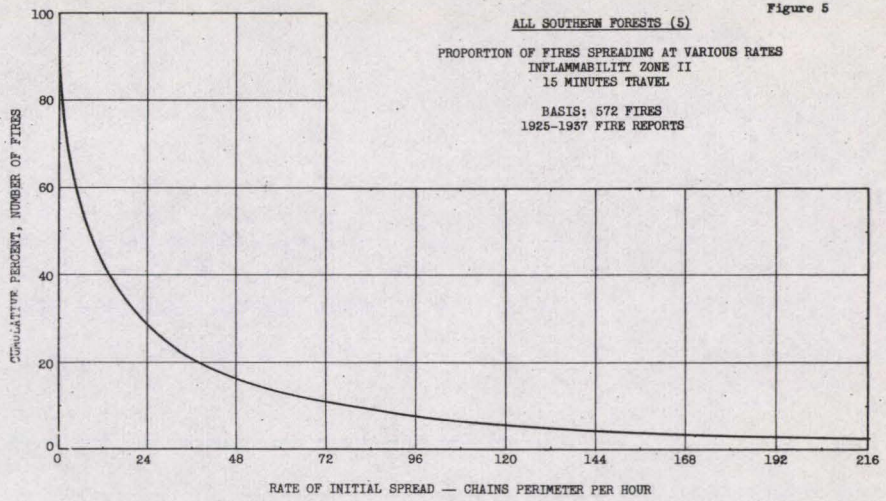


Figure 6

ALL SOUTHERN FORESTS (4)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
½ HOUR TRAVEL

BASIS: 123 FIRES
1925-1937 FIRE REPORTS

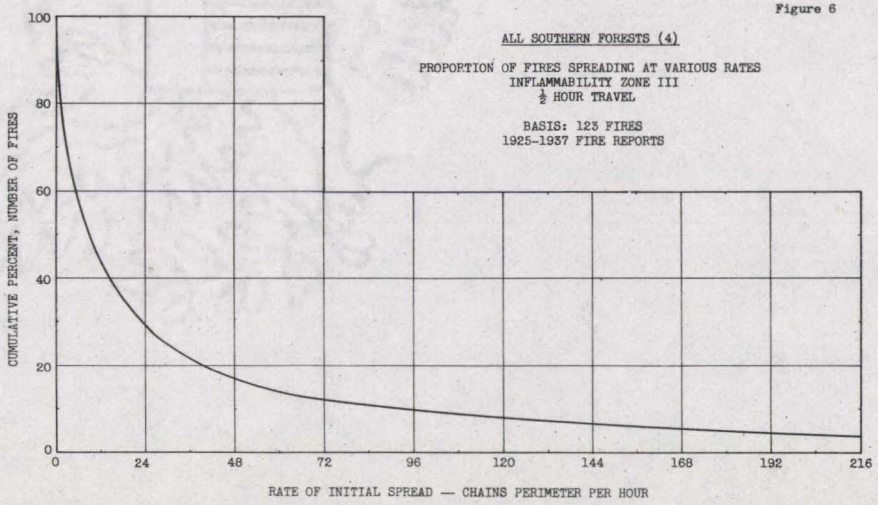


Figure 7

ALL SOUTHERN FORESTS (4)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE IV
½ HOUR TRAVEL

BASIS: 258 FIRES
1925-1937 FIRE REPORTS

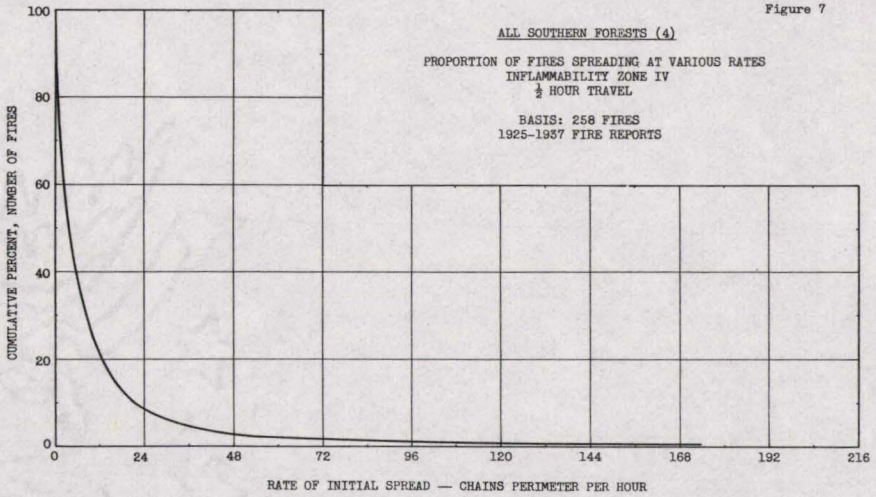


Figure 8

ALL SOUTHERN FORESTS (4)

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE V
1 HOUR TRAVEL

BASIS: 39 FIRES
1925-1937 FIRE REPORTS

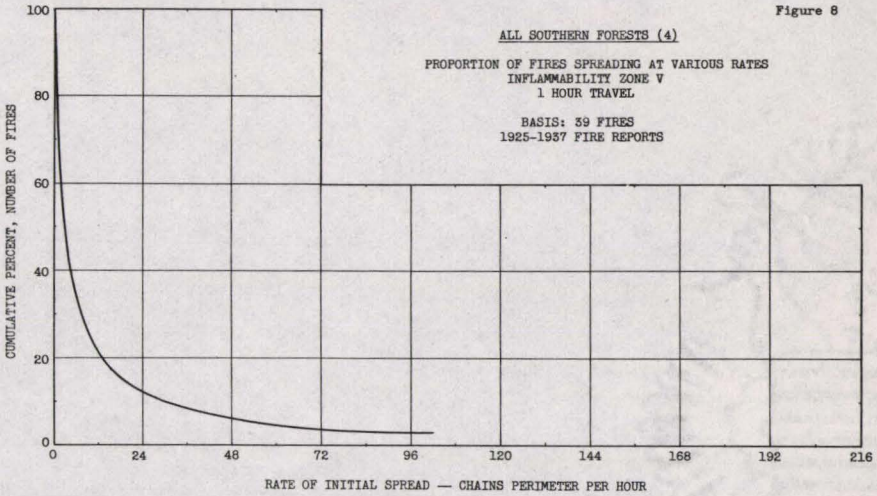


Figure 9

ALL SOUTHERN FORESTS

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE VI
EXTENDED TRAVEL

BASIS: 37 FIRES
1925-1937 FIRE REPORTS

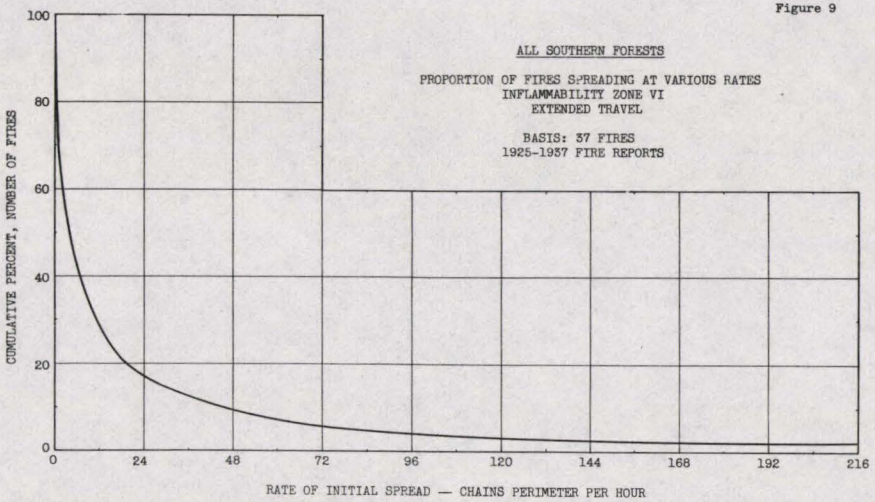


Figure 10

ANGELES NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 238 FIRES
1925-1937 FIRE REPORTS

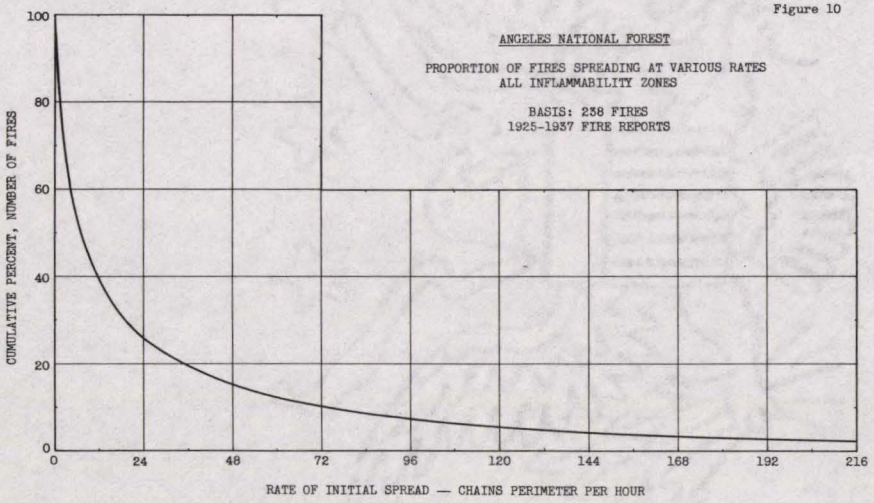


Figure 11

ANGELES NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
15 MINUTES TRAVEL

BASIS: 116 FIRES
1925-1937 FIRE REPORTS

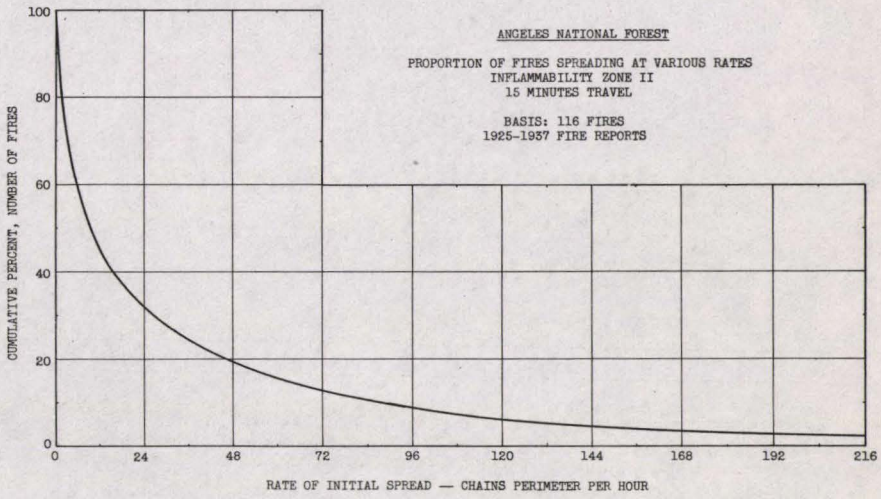


Figure 12

CLEVELAND NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 282 FIRES
1925-1937 FIRE REPORTS

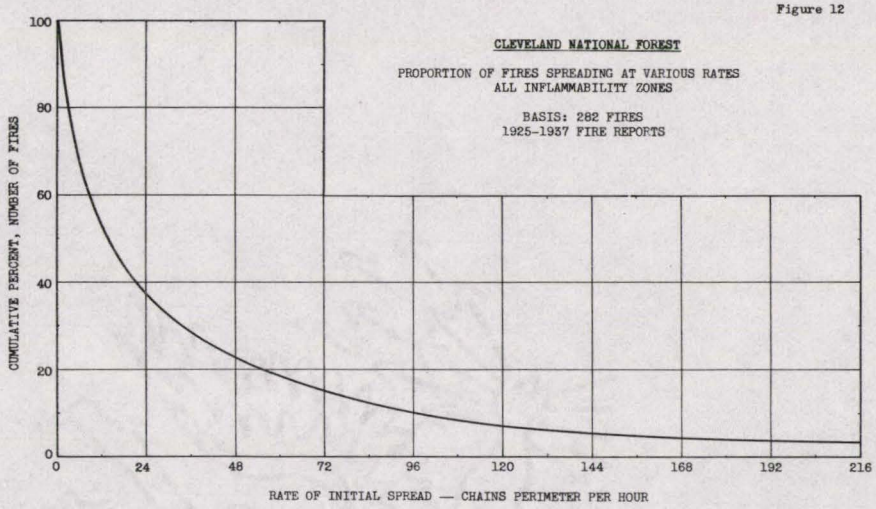


Figure 13

CLEVELAND NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
15 MINUTES TRAVEL

BASIS: 72 FIRES
1925-1937 FIRE REPORTS

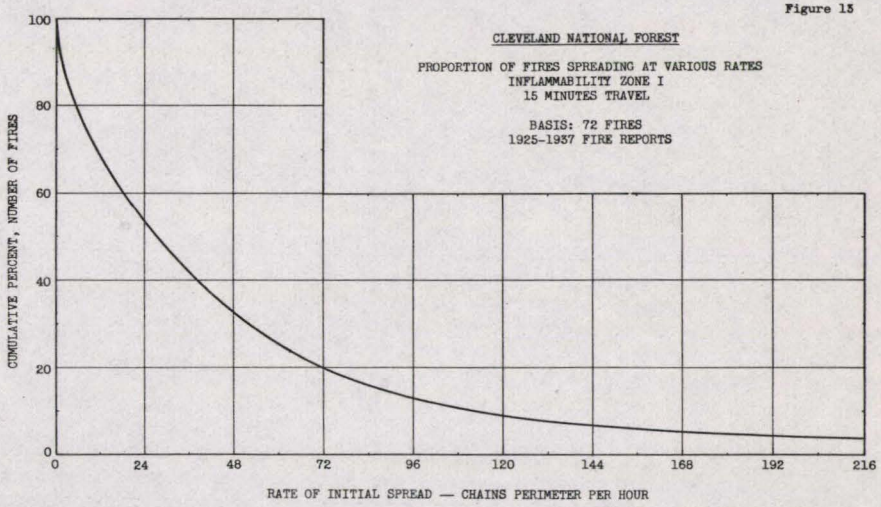


Figure 14

CLEVELAND NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
15 MINUTES TRAVEL

BASIS: 140 FIRES
1925-1937 FIRE REPORTS

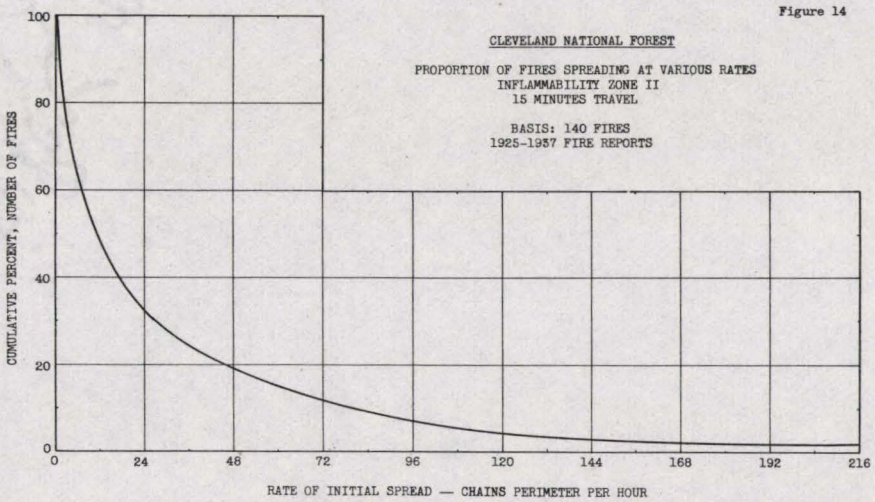


Figure 15

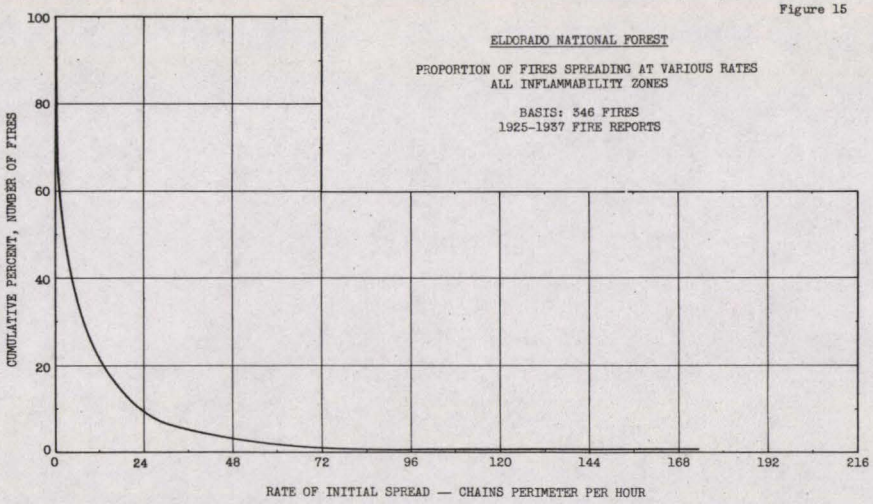


Figure 16

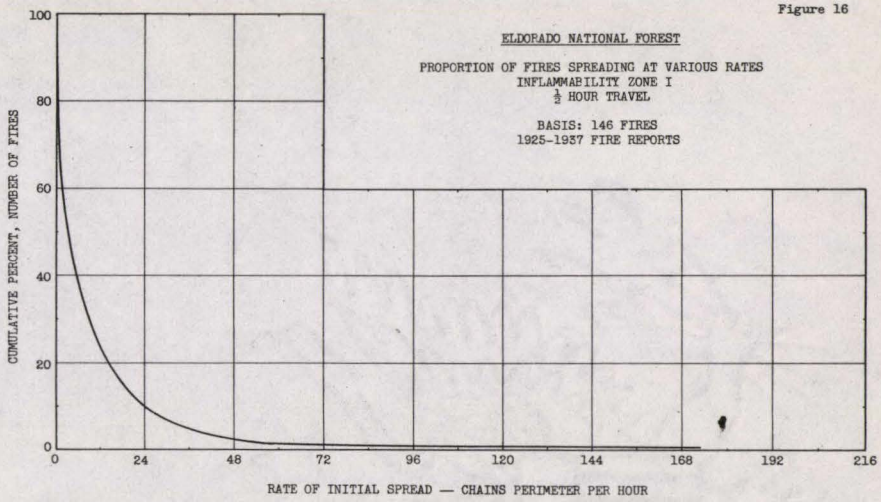


Figure 17

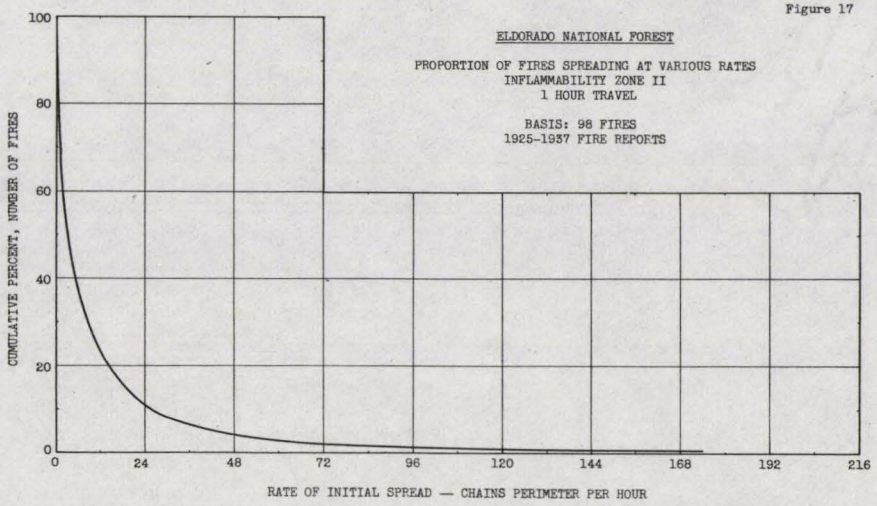


Figure 18

KLAMATH NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 767 FIRES
1925-1937 FIRE REPORTS

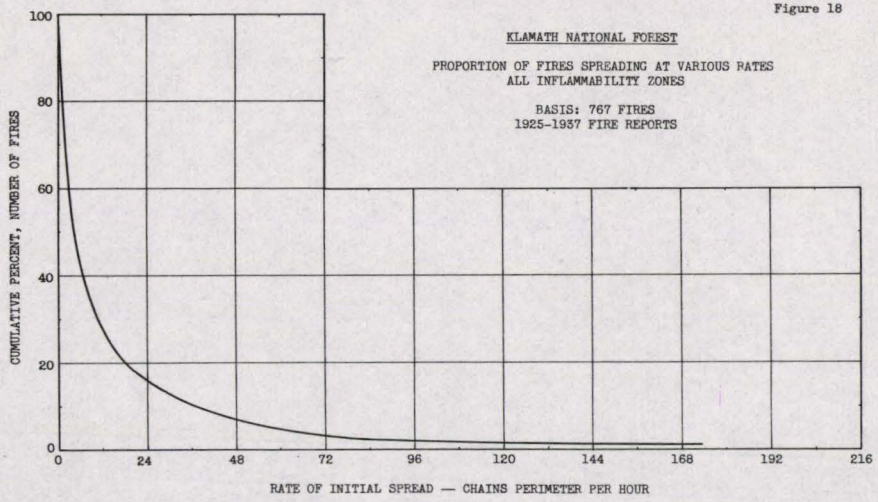


Figure 19

KLAMATH NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
½ HOUR TRAVEL

BASIS: 188 FIRES
1925-1937 FIRE REPORTS

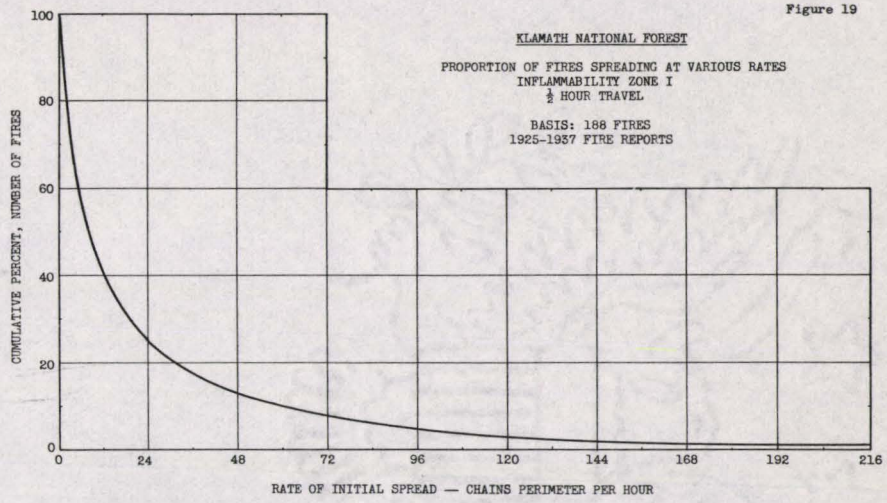


Figure 20

KLAMATH NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 137 FIRES
1925-1937 FIRE REPORTS

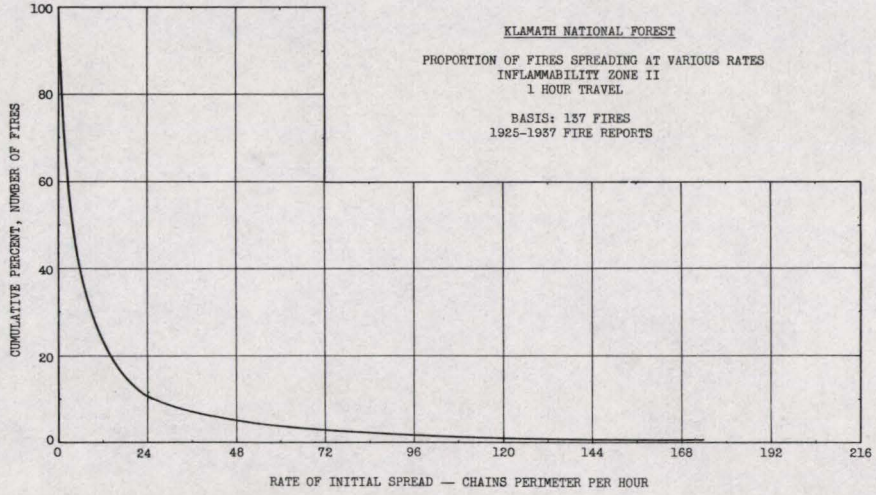


Figure 21

KLAMATH NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 341 FIRES
1925-1937 FIRE REPORTS

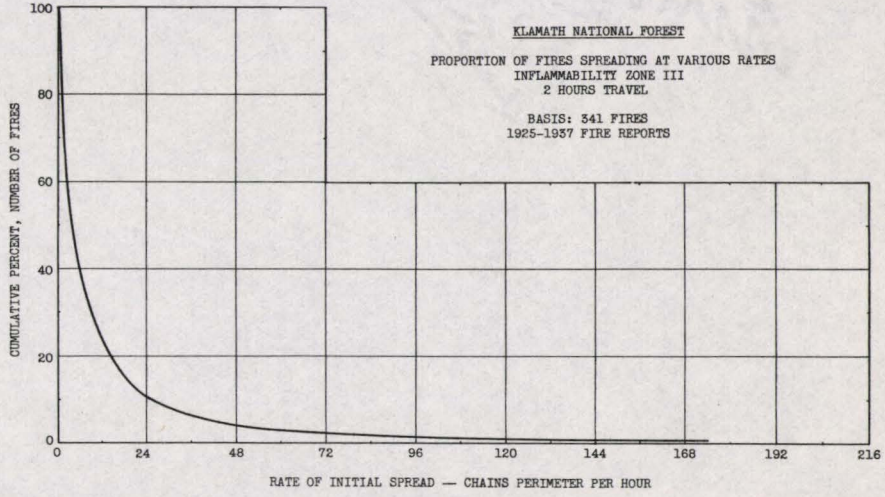


Figure 22

LASSEN NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 794 FIRES
1925-1937 FIRE REPORTS

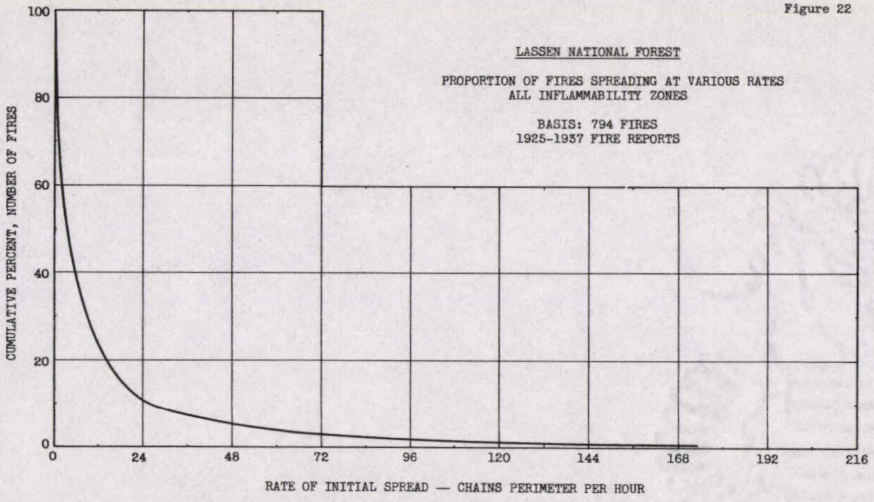


Figure 23

LASSEN NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
½ HOUR TRAVEL

BASIS: 211 FIRES
1925-1937 FIRE REPORTS

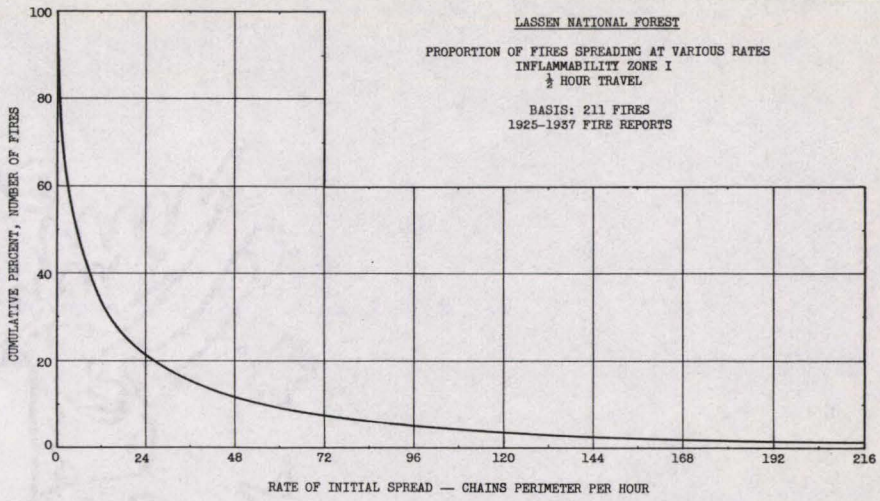


Figure 24

LASSEN NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 454 FIRES
1925-1937 FIRE REPORTS

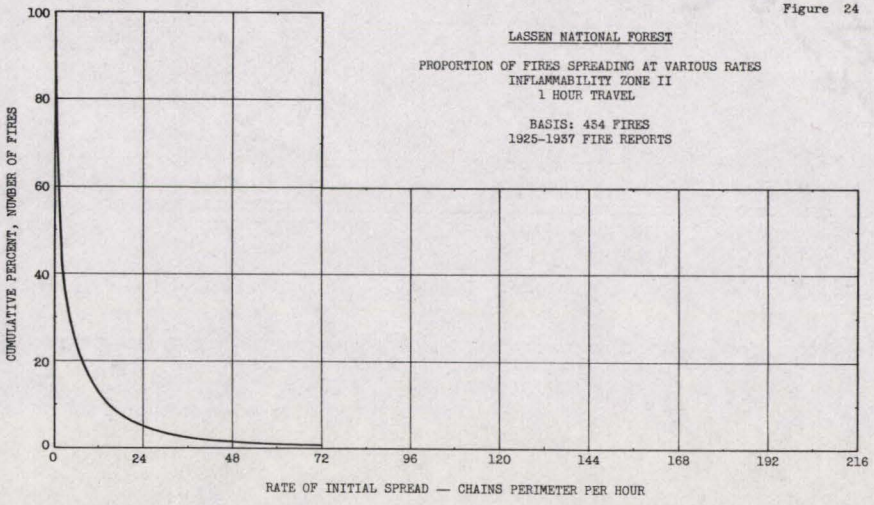


Figure 25

LASSEN NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 86 FIRES
1925-1937 FIRE REPORTS

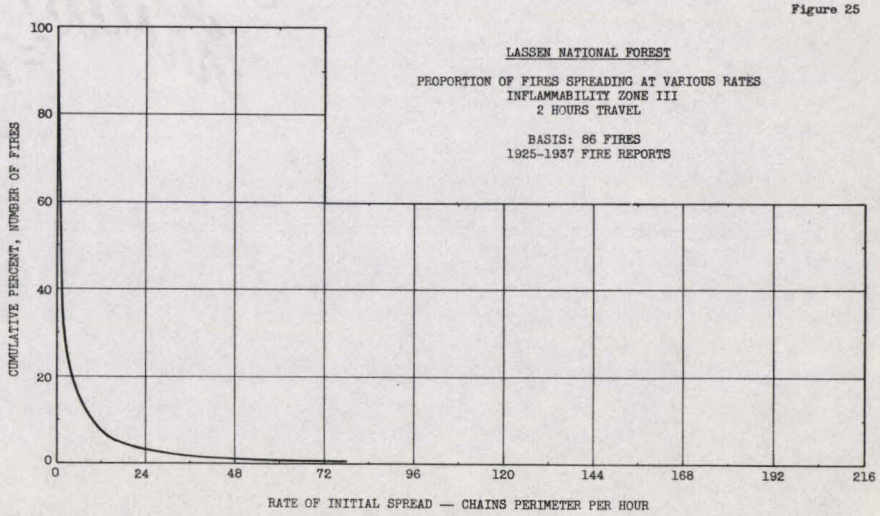


Figure 26

LOS PADRES NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 255 FIRES
1925-1937 FIRE REPORTS

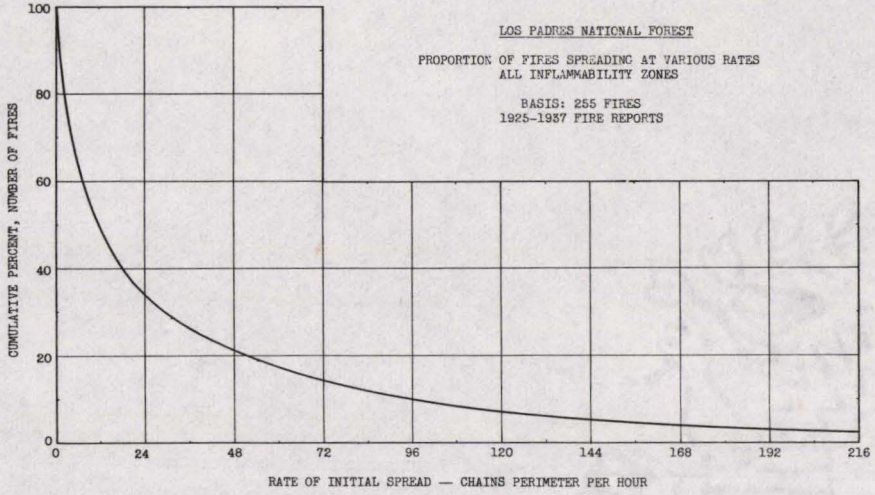


Figure 27

LOS PADRES NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
15 MINUTES TRAVEL

BASIS: 88 FIRES
1925-1937 FIRE REPORTS

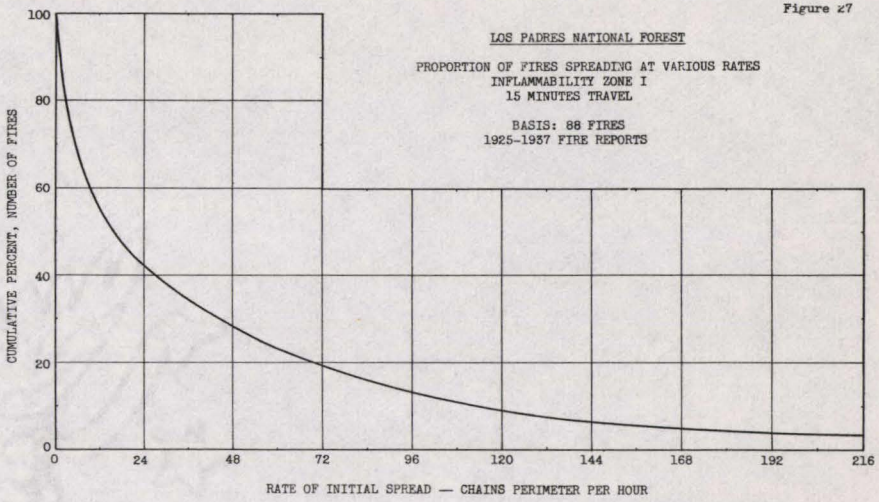


Figure 28

LOS PADRES NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
15 MINUTES TRAVEL

BASIS: 107 FIRES
1925-1937 FIRE REPORTS

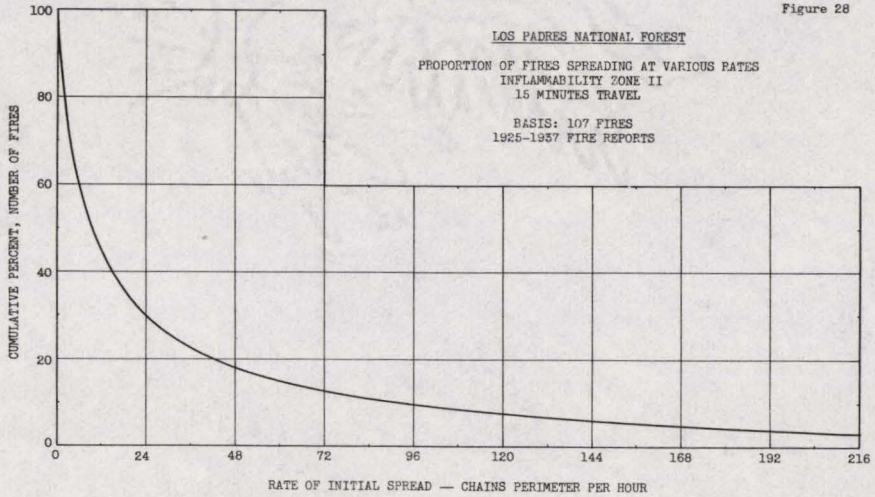


Figure 29

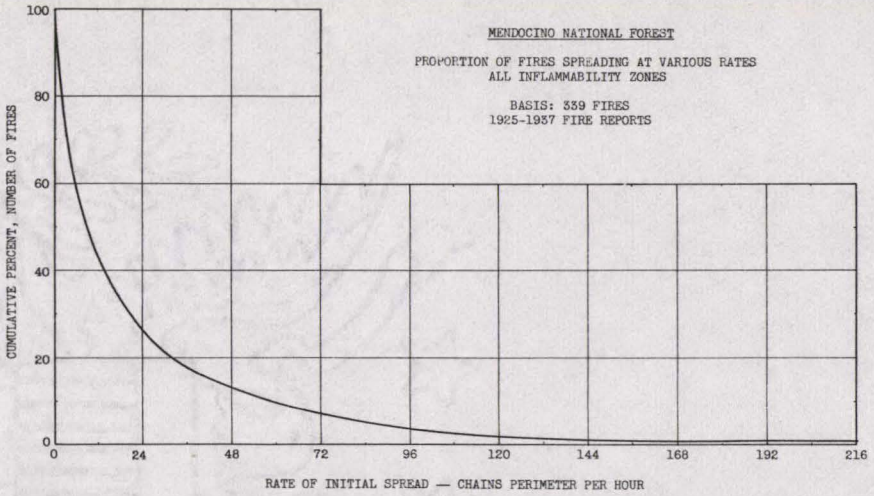


Figure 30

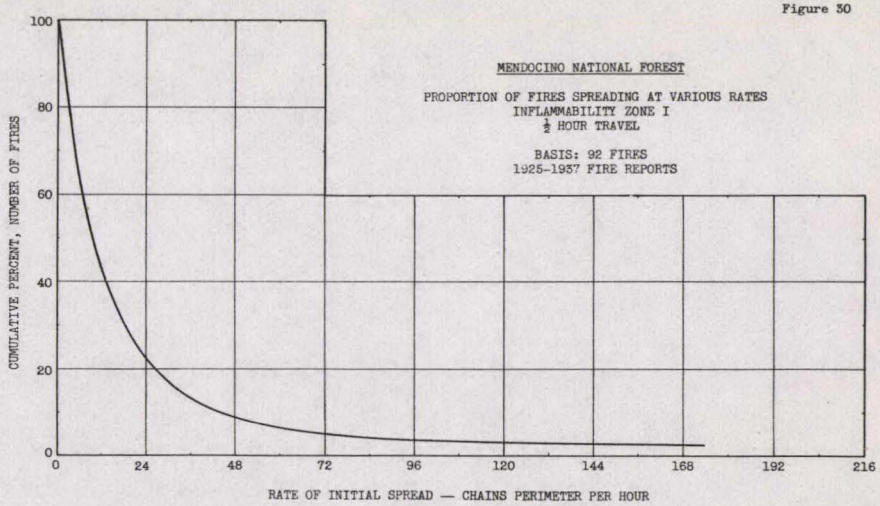


Figure 31

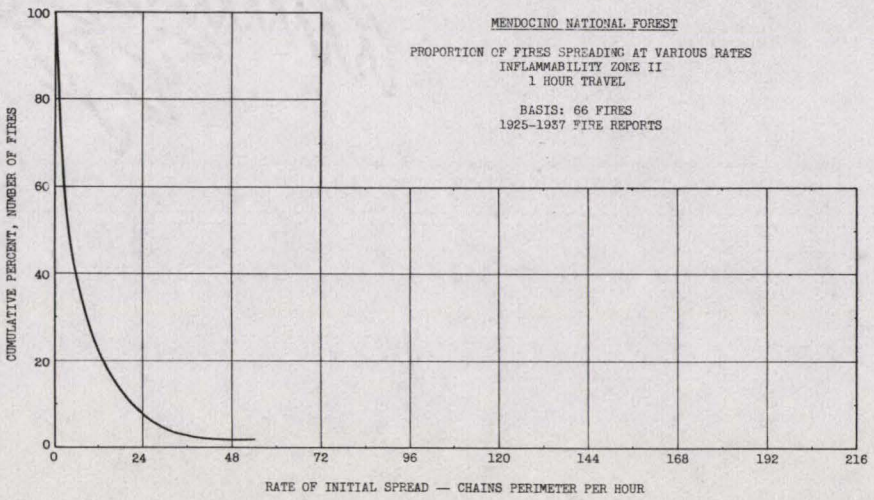


Figure 32

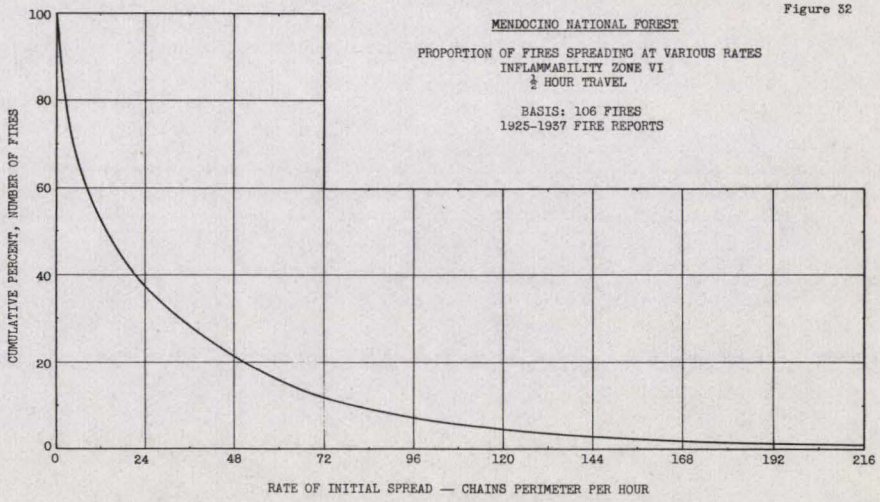


Figure 33

MODOC NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 504 FIRES
1925-1937 FIRE REPORTS

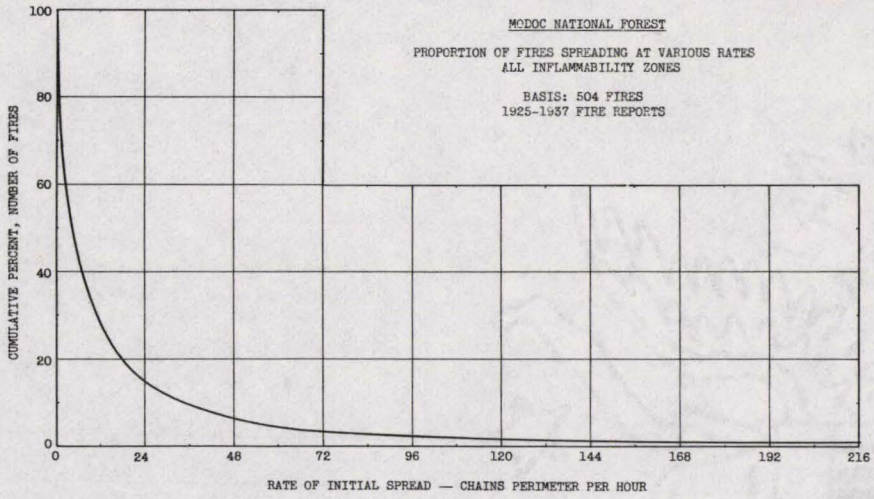


Figure 34

MODOC NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 356 FIRES
1925-1937 FIRE REPORTS

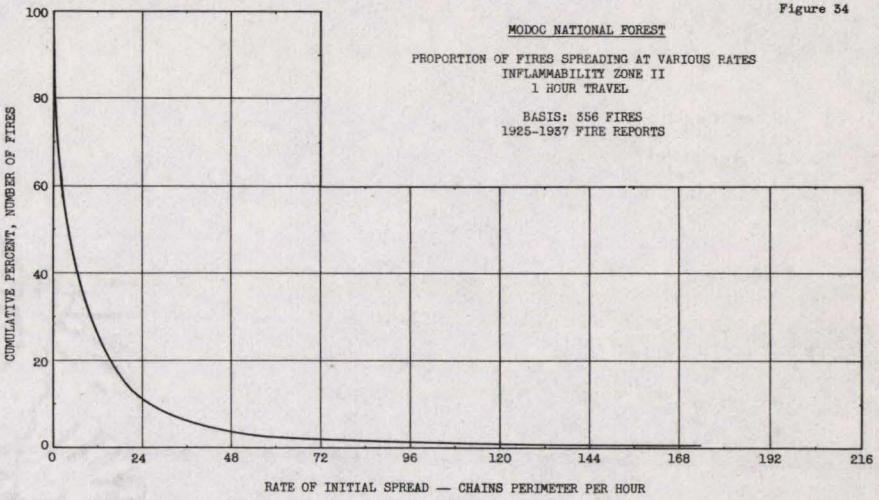


Figure 35

MODOC NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 59 FIRES
1925-1937 FIRE REPORTS

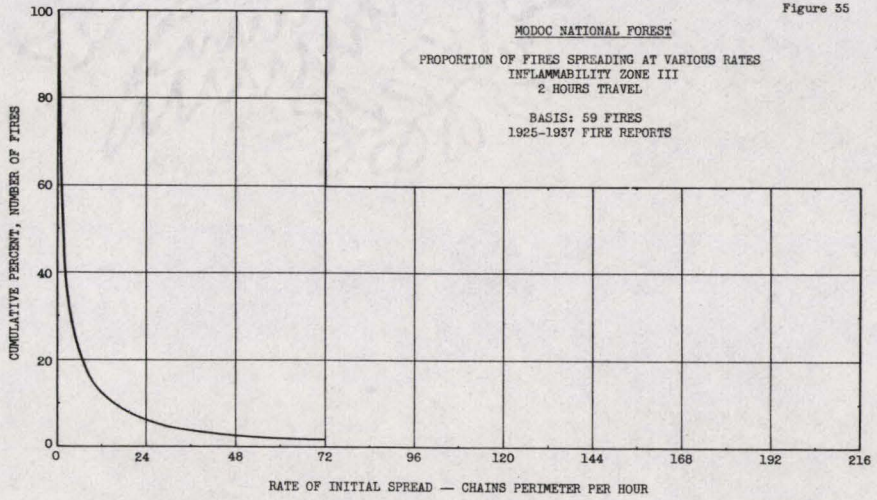
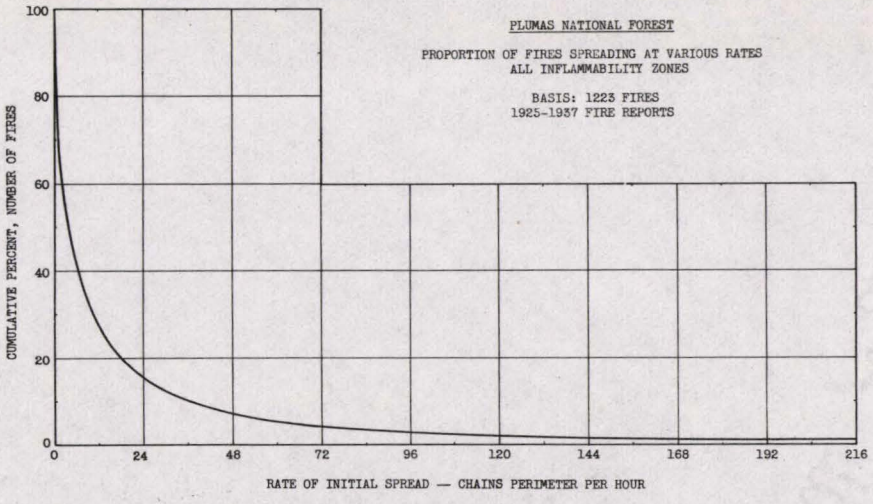


Figure 36



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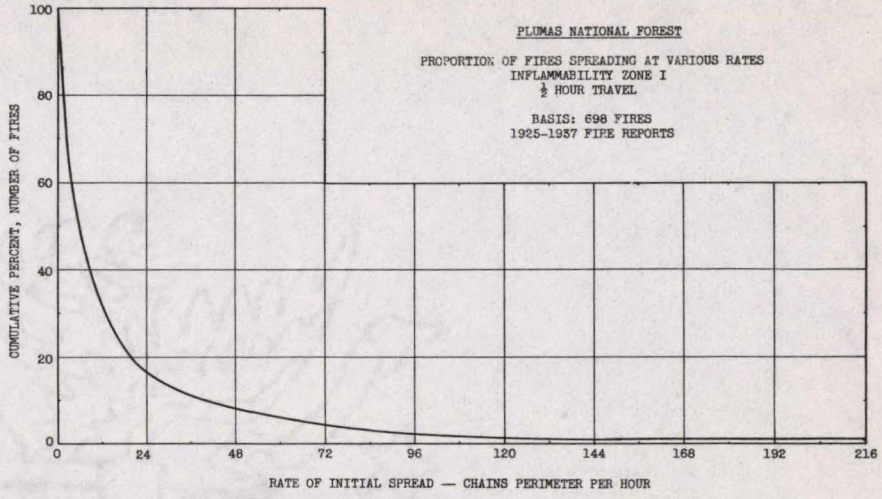

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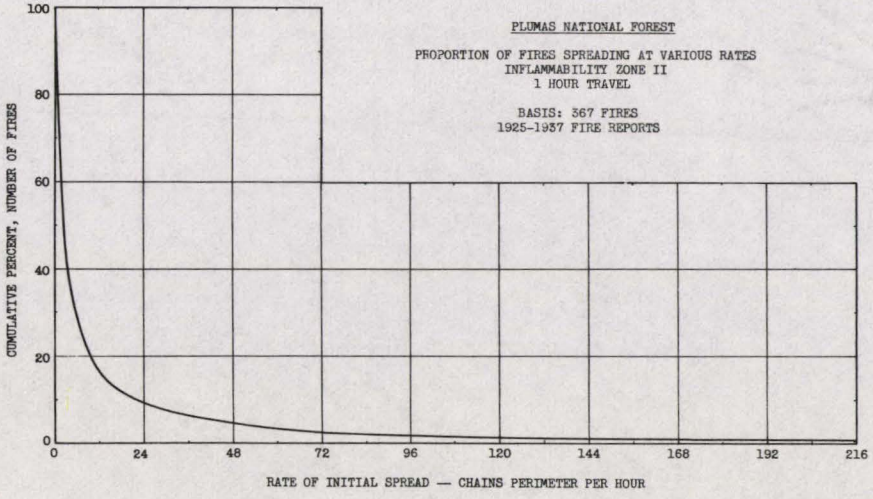

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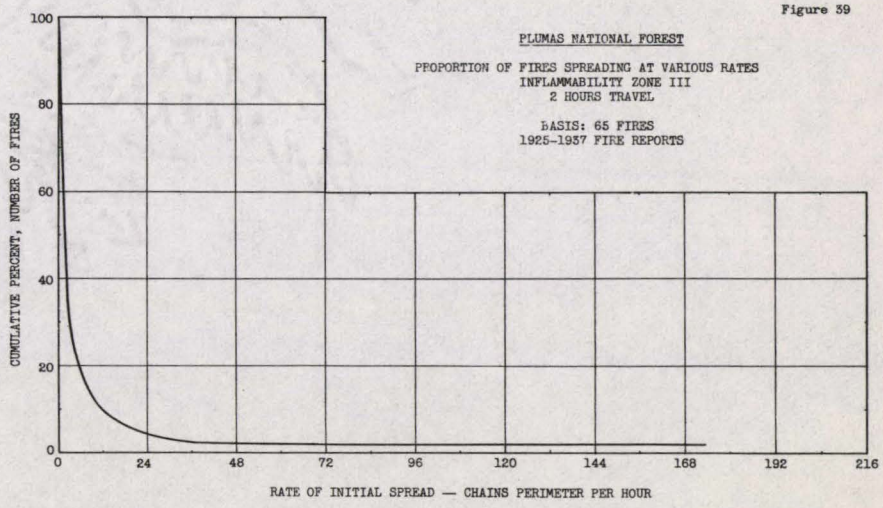


Figure 40

SAN BERNARDINO NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 529 FIRES
1925-1937 FIRE REPORTS

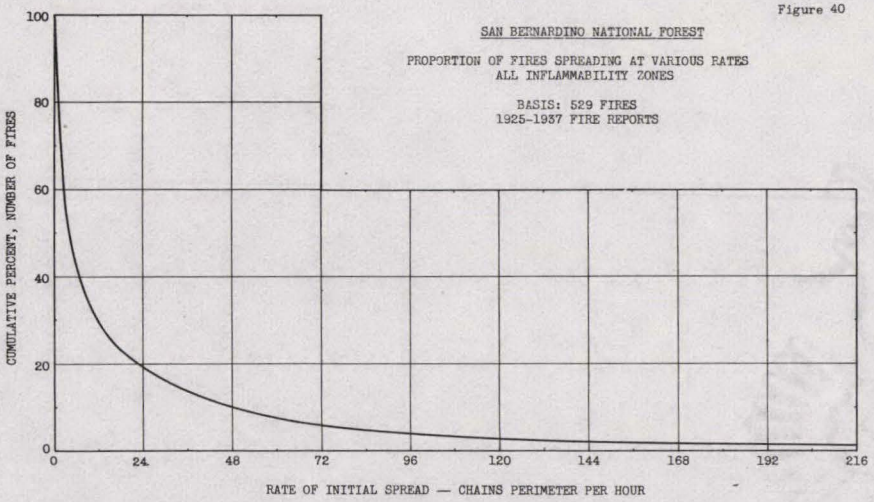


Figure 41

SAN BERNARDINO NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
15 MINUTES TRAVEL

BASIS: 209 FIRES
1925-1937 FIRE REPORTS

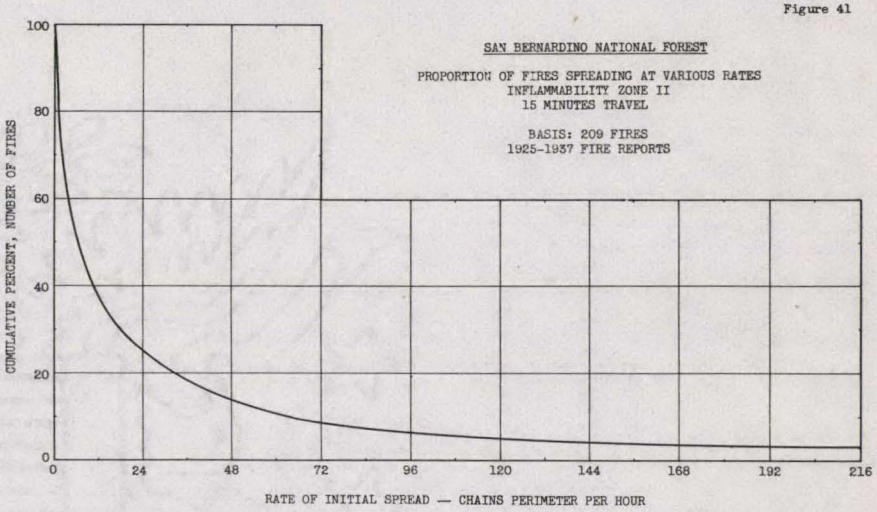


Figure 42

SAN BERNARDINO NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE IV
½ HOUR TRAVEL

BASIS: 204 FIRES
1925-1937 FIRE REPORTS

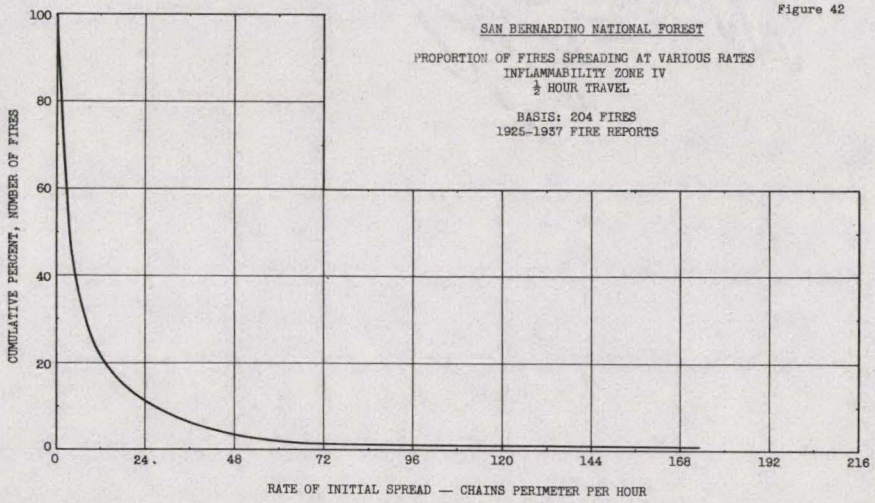


Figure 43

SEQUOIA NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 364 FIRES
1925-1937 FIRE REPORTS

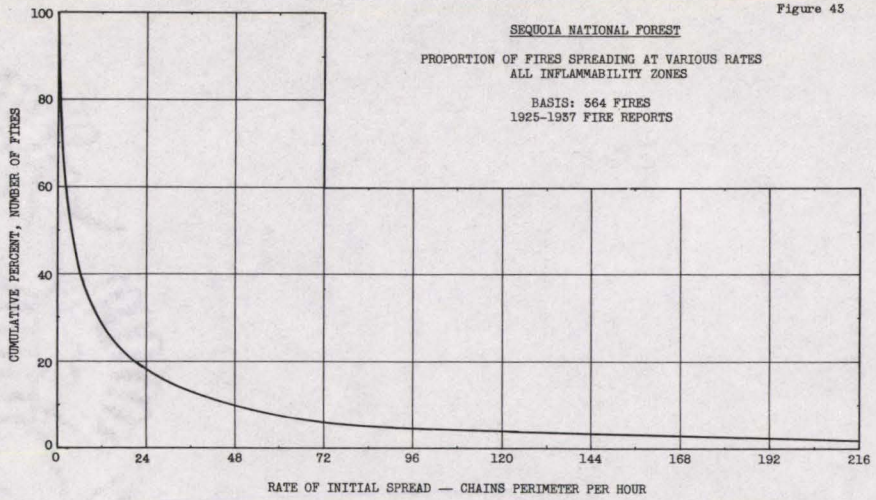


Figure 44

SEQUOIA NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
½ HOUR TRAVEL

BASIS: 108 FIRES
1925-1937 FIRE REPORTS

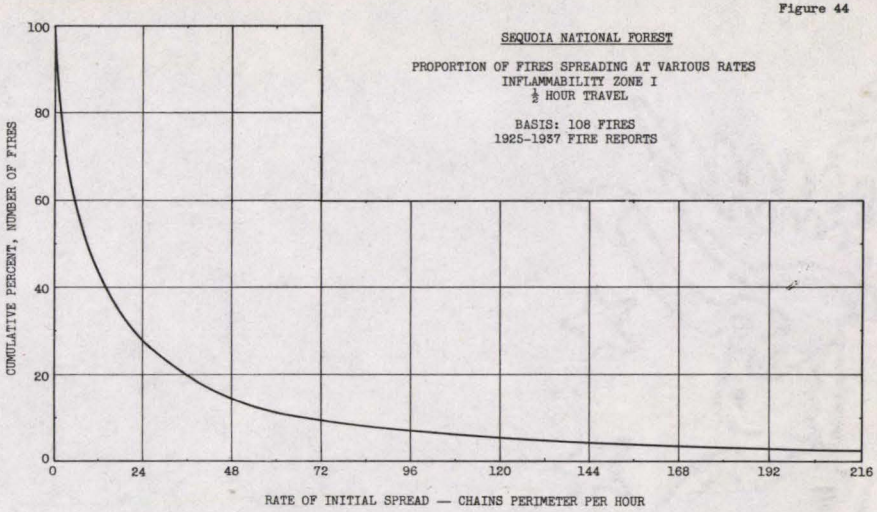


Figure 45

SEQUOIA NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 86 FIRES
1925-1937 FIRE REPORTS

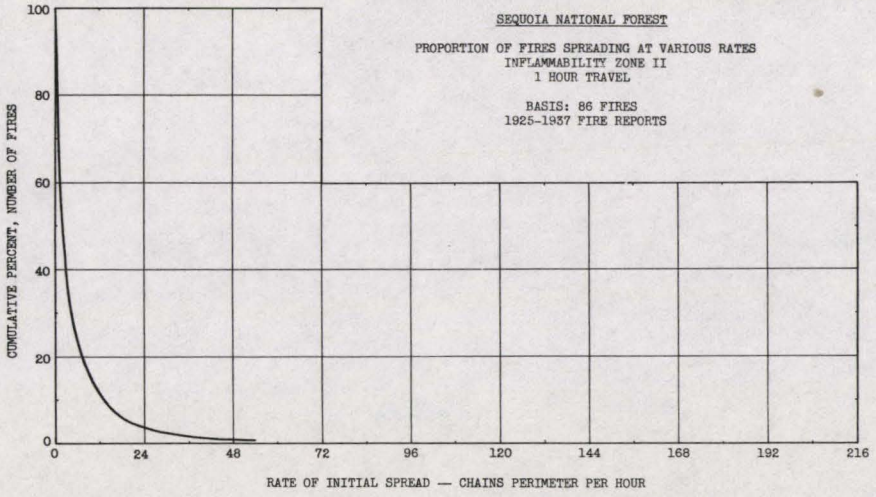
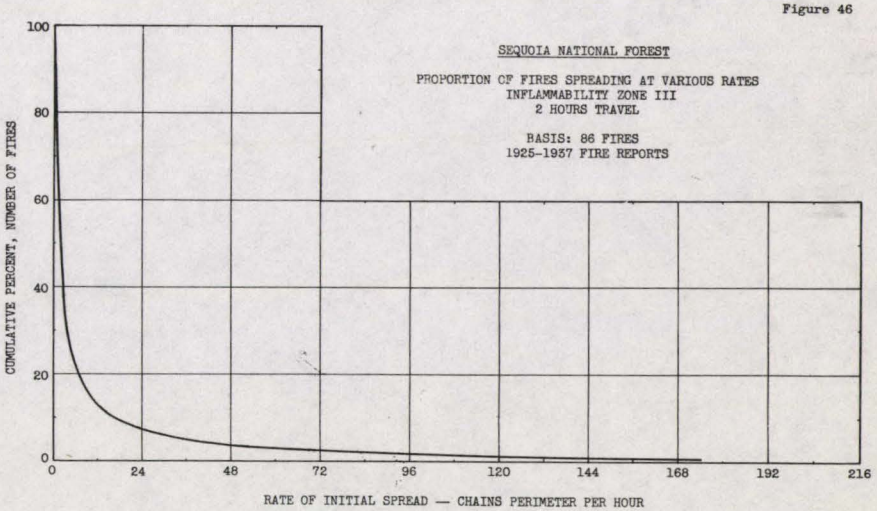


Figure 46

SEQUOIA NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 86 FIRES
1925-1937 FIRE REPORTS



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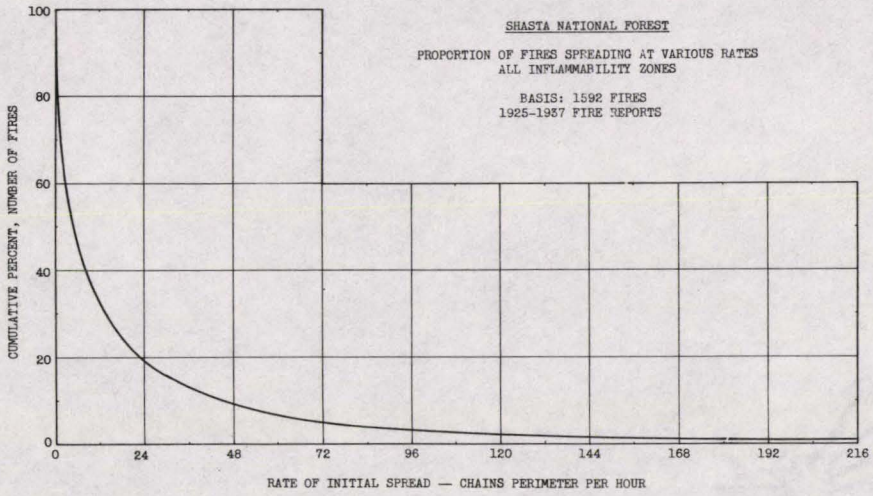


Figure 48

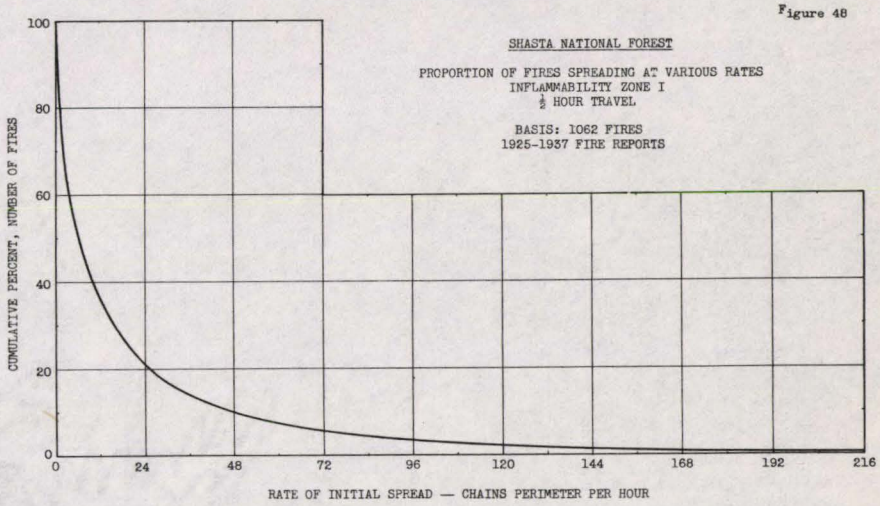
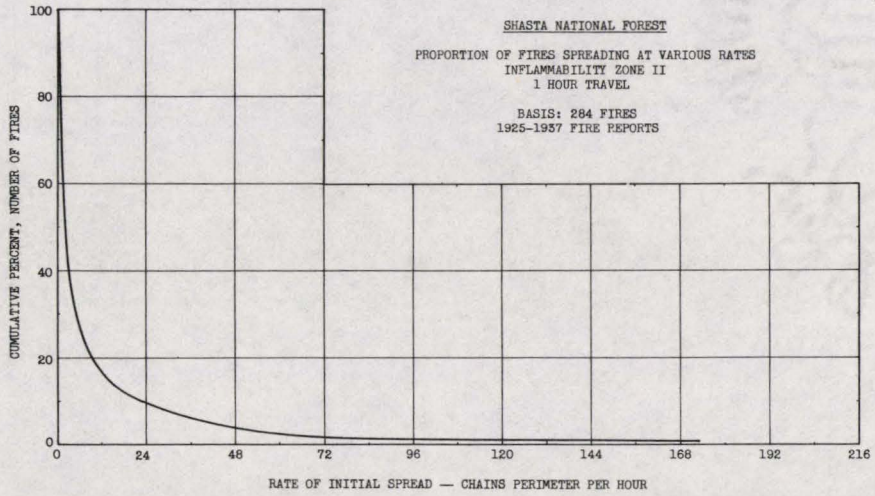


Figure 49



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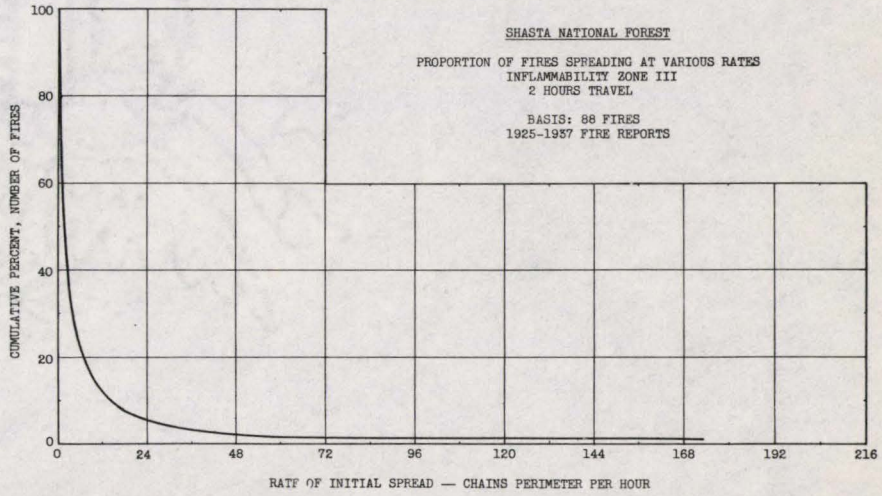

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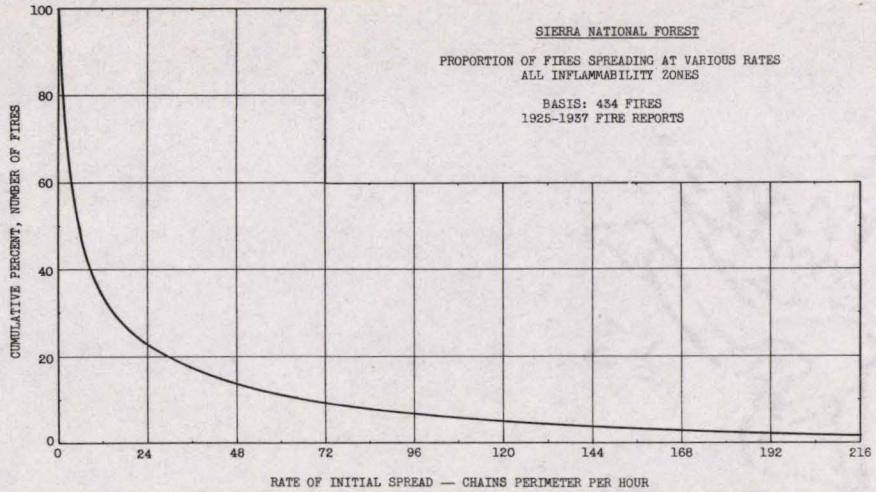
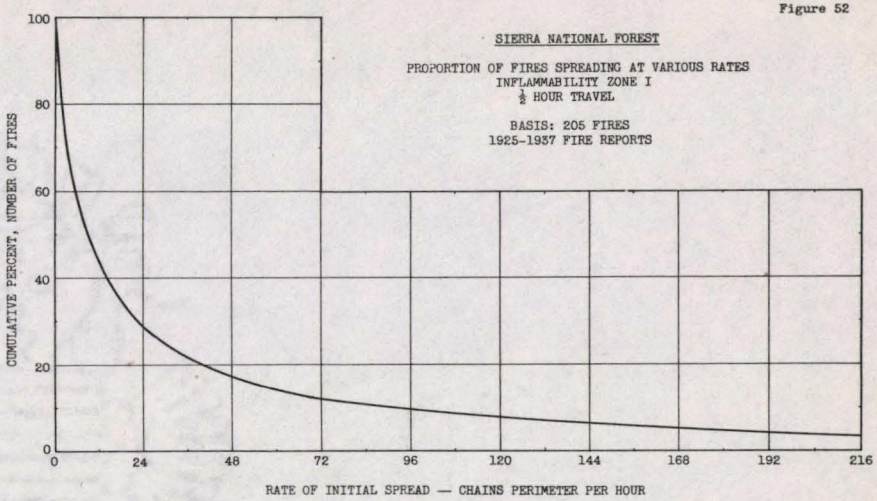


Figure 52



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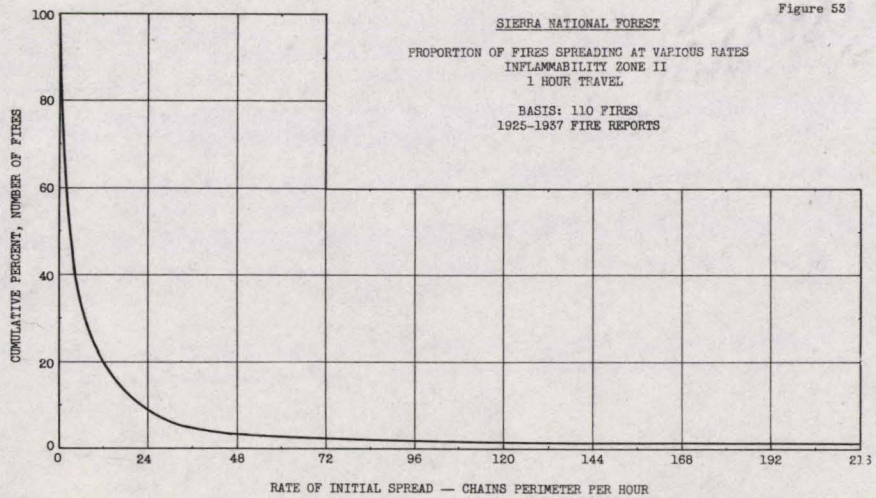

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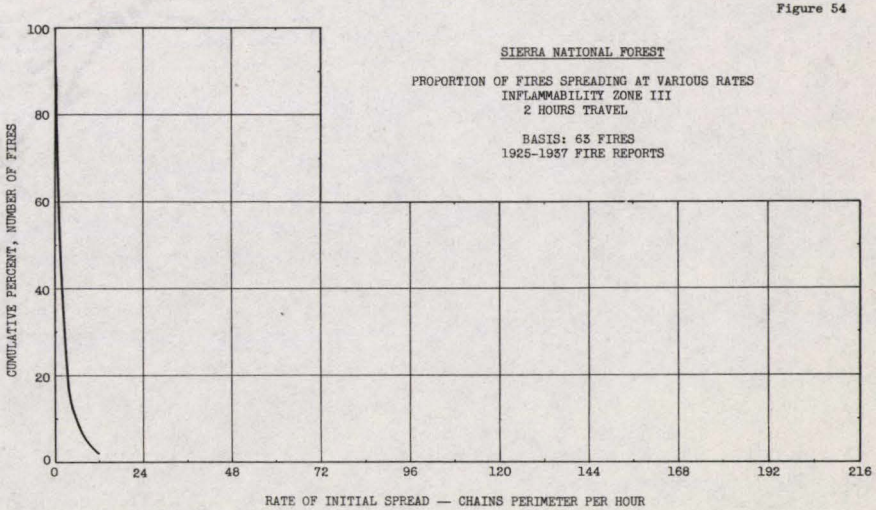

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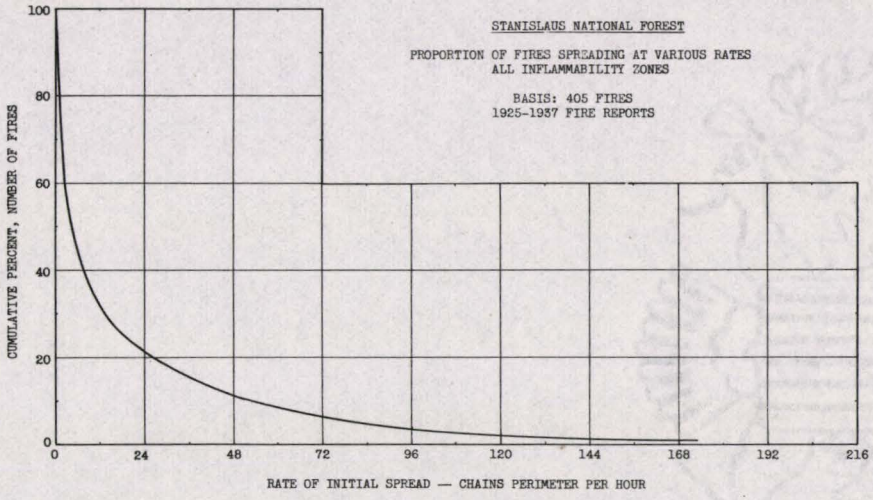

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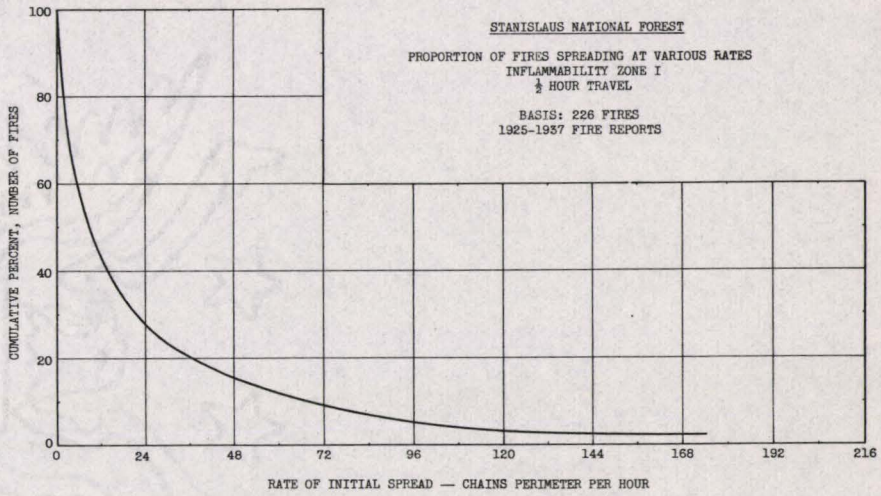

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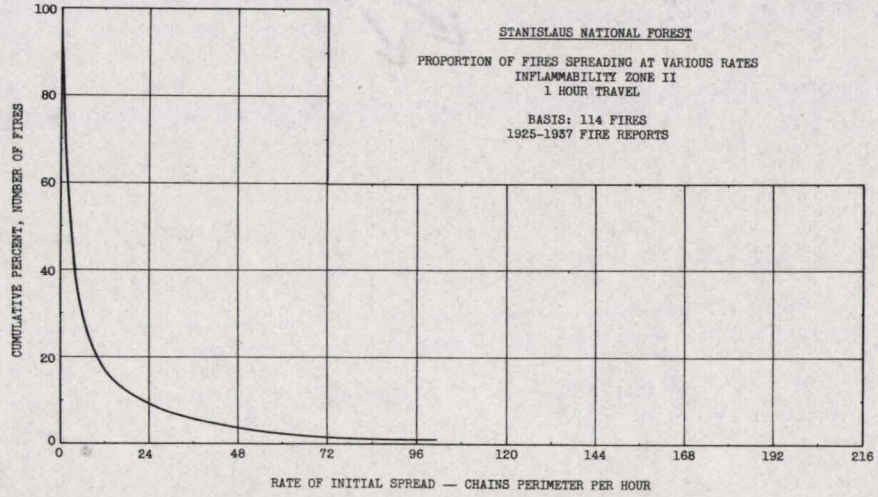

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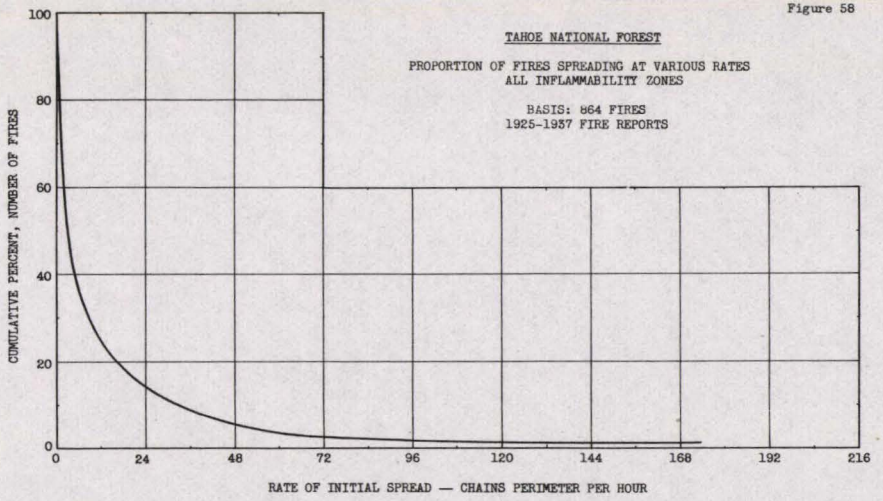

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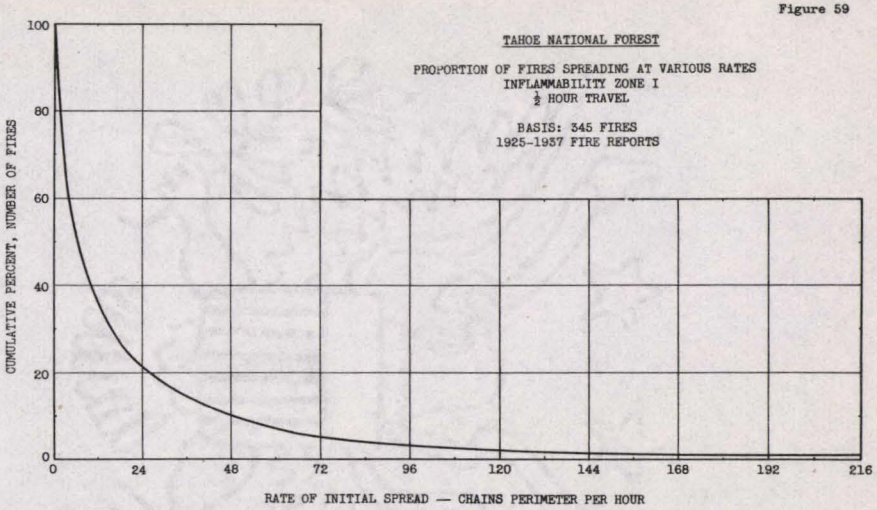

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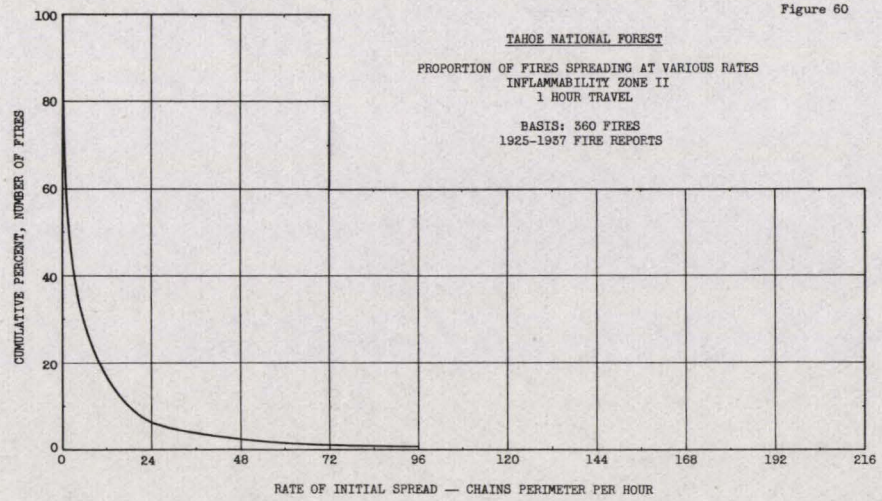

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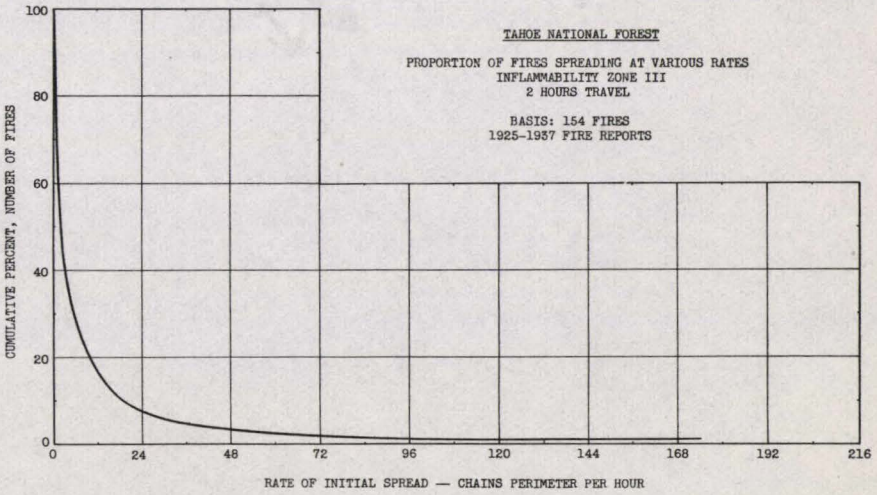


Figure 62

TRINITY NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
ALL INFLAMMABILITY ZONES

BASIS: 605 FIRES
1925-1937 FIRE REPORTS

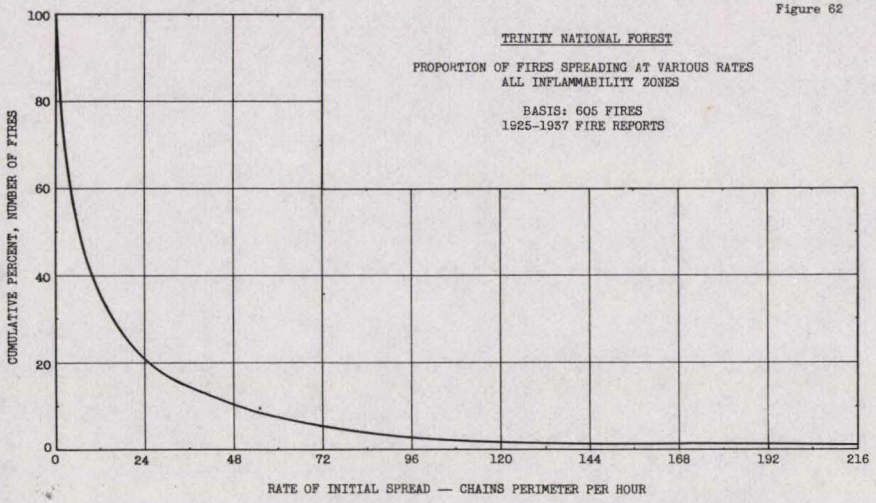


Figure 63

TRINITY NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE IA

BASIS: 41 FIRES
1925-1937 FIRE REPORTS

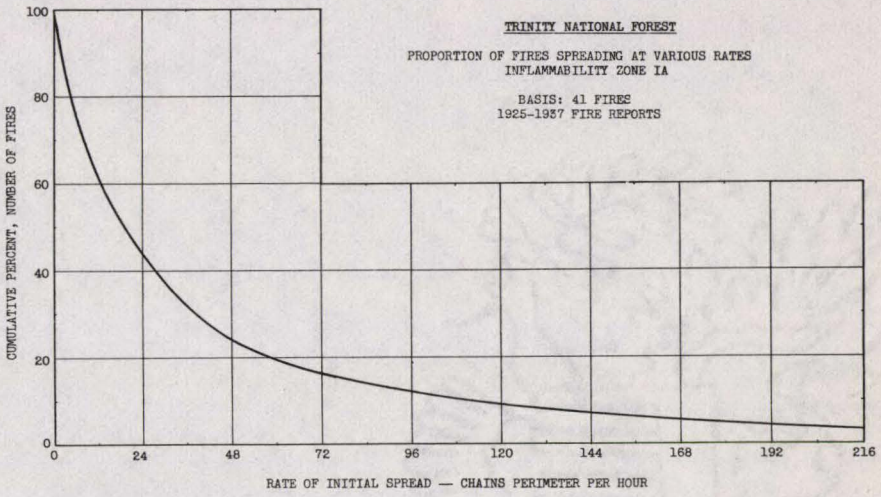


Figure 64

TRINITY NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE I
½ HOUR TRAVEL

BASIS: 152 FIRES
1925-1937 FIRE REPORTS

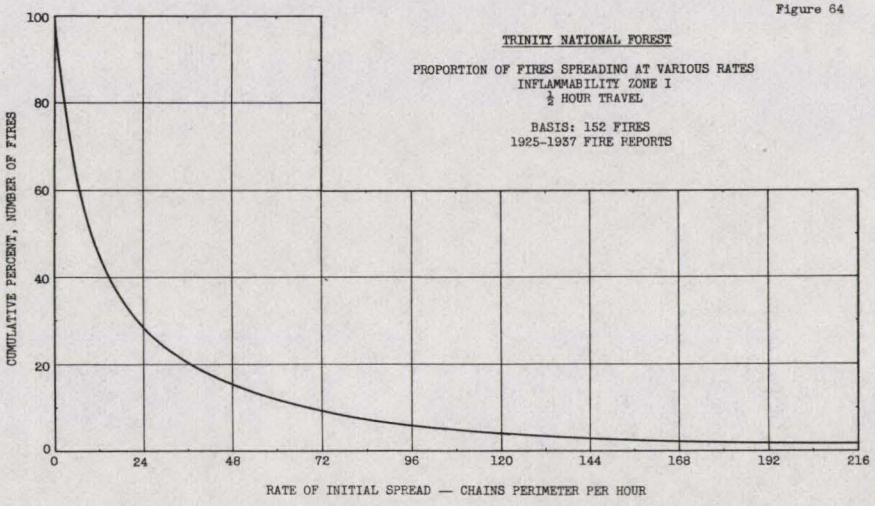


Figure 65

TRINITY NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE II
1 HOUR TRAVEL

BASIS: 250 FIRES
1925-1937 FIRE REPORTS

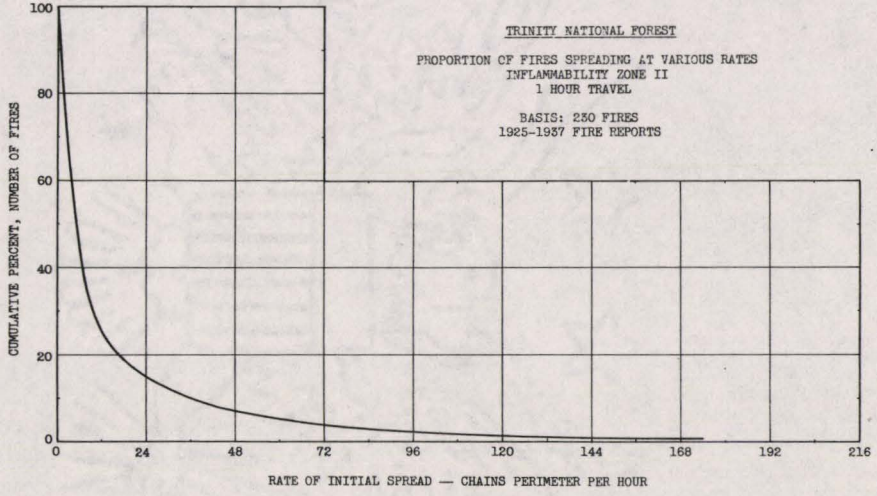
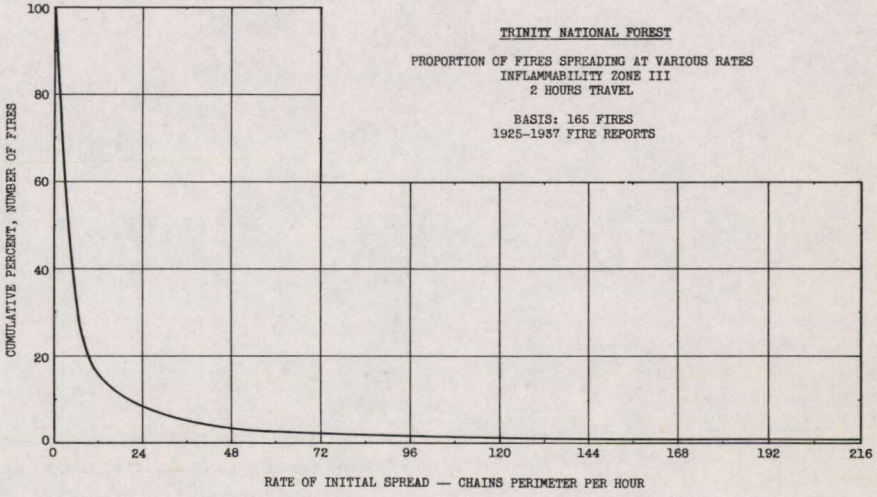


Figure 66

TRINITY NATIONAL FOREST

PROPORTION OF FIRES SPREADING AT VARIOUS RATES
INFLAMMABILITY ZONE III
2 HOURS TRAVEL

BASIS: 165 FIRES
1925-1937 FIRE REPORTS



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